Horticulture in Arid and Semi-Arid Regions, pp 475-488

New India Publishing Agency, New Delhi, India

27

Cultivation of Cactus Pear for Higher Income in Arid Zone

Kamlesh Kumar and Dhurendra Singh

Introduction

Climate change has become one of the biggest challenges for the sustainable crop production. Prolonged droughts and desertification are among the issues faced by Indian hot arid zone where the rural poor and smallholders are most heavily affected. If people are to survive in these ever harsher conditions, their crops need to withstand drought, high temperatures and poor soils. Cactus crops are gaining increasing interest across the globe, in particular cactus pear or prickly pear {*Opuntia ficus indica* (L) Mill.} because of its unique characteristics which provide resilience to the harsh ecological conditions. Cactus pear is able to grow on land where no other crops are able to grow; it can be used to restore degraded land. It is the only crop that can be relied on when everything else fails. Cactus pear is grouped as CAM plant (Crassulacean Acid Metabolism), a photosynthesis mechanism evolved in some plants as an adaptation to arid conditions. In a plant using full CAM, the stomata in the leaves remain shut during the day to reduce evapotranspiration, but open at night to collect carbon dioxide (CO_2). At night carbon dioxide is stored as 4 carbon acid malate in cell vacuoles. The malate is transported to chloroplasts where it is converted back to CO_2 during day which is used in the process of photosynthesis (Ting, 1985). The cactus pear plants though shallow rooted but have capacity to absorb and store water in its parenchyma even under unfavourable climatic conditions due to high mucilage production in both cladode and fruits. Besides, peculiar adaptations to water scarcity and high as well as low temperature is because of reduced leaf tissues and cuticular wax covering of cladodes and fruit surfaces. (Saroj *et al*, 2017). The cactus pear fruit is an oval, elongated berry, with a thick pericarp and a juicy pulp and, in general, many hard seeds generally known as tuna. The fruits are of different colours, such as red, purple,

orange, yellow and green in colour which show the presence of various antioxidants. The high sugar and low acid blend of the fruit makes it delicious and palatable. The pericarp of ripe fruits accounts for 33% to 55%, while the pulp is 45% to 67%, and seeds 2% to 10%. The pulp is the edible part of the fruit and is composed of water (84% to 90%) and reducing sugars (10% to 15%). The pH value of fruits ranged (5.3 to 7.1) and the very low acidity (0.05% to 0.18% in citric acid) of the pulp, which strongly influences the processing operations. Sugars range from 10°Brix to 17°Brix and are mainly of the reducing type (Russel and Felker, 1987; Stintzing *et al.*, 2003). Cactus cladode (nopal) is rich in pectin, mucilage, minerals, polyphenols, nicotiflorin, vitamins, polyunsaturated fatty acids (palmitic acid, oleic acid, linoleic acid, linolenic acid *etc.*) and amino acids (glutamine, leucine, lysine, valine, arginine, phenylalanine and isoleucine). The nopal contains antioxidants and various flavonoids, particularly quercetin 3-methyl ether, a highly efficient radical scavenger. Chemical characterizations of nopal have studied by several workers and reported that it contains vitamins and minerals. Dehydrated nopals contain high levels of potassium content. Considering the lactose intolerance in certain parts of the population, nopals could be an alternative as source of calcium. Cactus nopal pulp has numerous compounds (dietary fibre, vitamin C, phenolic compounds) with the potential to provide important benefits like intestinal, cardiovascular, hepatic health, antioxidant activity and cancer prevention. The fresh young pads so called nopal are excellent source of proteins including essential amino acids and vitamins. The value added products of cactus pear could also supplement to nutritional security and human health. The succulent vegetative parts are called as pads or cladodes which are modified stem (Kumar *et al.*, 2017).

The propagation and cultivation of spineless varieties may provide the feed stuffs to domestic animals during summer season in arid ecosystems, when there is lack of forage/grass due to harsh climatic conditions. Even today cactus pear is treated as underutilized crop in India, though it has multiple utility. In general, no special treatments (fertilizer application, pruning and treatment against pests and diseases) are necessary for cactus establishment and cultivation. Supplemental irrigation may be applied during early period of establishment on first year. Cacti are ready for commercially use after 3- 4 years of planting. A well managed cactus orchard can remain productive for about 4-5 decades.

Present status in India and global scenario

Cactus pear is now-a-days part of the agricultural systems and natural environment. The most important economic species in the world is *Opuntia ficus-indica* (L.) Mill. Presently, it is grown in Mexico, Malta, Spain, Sicily,

Italy, Greece, Libya, Tunisia, Morocco, Algeria, Lebanon, Syria, Egypt, Saudi Arabia, Yemen, Israel, Chile, Brazil, Turkey, France, Bulgaria, Portugal, Albania, Cyprus, United States (Kauthale *et al*, 2017). The area covered under cactus cultivation is presented in table 1.

Table 1: Current world scenario of cactus cultivation

S.N.	Country	Cultivated area (000 ha)
1.	Brazil	600
2.	Tunisia	600
3.	Mexico	230
4.	Morocco	150
5.	Algeria	150
6.	Italy	70
7.	Other South American Countries	75
8.	Other North American countries	16
	Total	1891

Source: International Cactus Pear Workshop: Development of a cactus pear agro-industry for the Sub-Sahara Africa Region Bloemfontein, South Africa, 27-28 January 2015.

It can be found growing well from sea level to 5100 meters above sea level in Peru and from Canada to Patagonia and Argentina. The first record of modern cactus pear cultivation techniques using the best varieties were found in Mexico, Zacatecas, San Luis Potosi, Aguascalientes, Jalisco and Guanajuato in the 1940s and 1950s. Cactus pear is now the most reliable and even profitable option for utilizing rainfed semi-arid lands in the semi-arid regions of central Mexico. It is the crop of choice over corn or dry beans in areas exposed to drought, while in slightly improved areas, it supplemented the income of the growers (Josh *et al*, 2017).

Cultivated of cactus pear was started long back in many countries of the world but, in India, its commercial cultivation is yet to start. In India 33 Opuntia clones were introduced by Dr. Peter Felker, Texas, USA at the Nimbkar Agricultural Research Institute at Phalton, India in 1987 as a part of an Indo-US collaborative research programme on Opuntia. All the introduced clones grown well under the semi arid agro-climatic conditions of western Maharashtra and it was reported that some clones produced fruits also (Singh, 2003). Till so for (Kauthale *et al*, 2017), it is at the research stage with limited field trials initiated by Central Arid Zone Research Institute (ICAR- CAZRI), Jodhpur and in Kutch district of Gujarat in few select areas with the support of International Center for Agricultural Research in the Dry Areas (ICARDA). The comprehensive work on Cactus was started by NARI with the collection of good number of imported accessions. However the work could not be pursued to its logical end. During

the last two decades the research was conducted by many public sector research Institutes in India especially those are working in arid agricultural crops, but the outcome of this work is yet reach to the farmers.

Recently, in India the research work on Cactus pear has been undertaken by various Research Institutions *viz.*, ICAR-CAZRI, Jodhpur supported by ICARDA, ICAR-CIAH, Bikaner ICAR- IGFRI, Jhansi, ICAR- CSSRI, Karnal. Field adaptation trials on farmer's field are being conducted through ICARDA programme by CAZRI and in Bundelkhand region by IGFRI and CAFRI. NDDB actively involved in spreading cactus among dairy farmers of Gujarat (Kauthale *et al*, 2017). Trials on planting seasons and irrigation management with cactus in various cropping models are in progress at CAZRI. Recently, research work on planting methods, performance of various accessions, exploitation and uses of vegetable type cactus (Kumar *et al*., 2017) and biomass production, was made at CIAH, Bikaner, CAFRI, Jhansi and CSSRI, Karnal. BAIF Development Research Foundation, Pune, a non-government organization initiated a comprehensive work on Cactus with the financial support of NABARD in 2015. The initiative was to cultivate this new crop on the farmer's field after standardizing the production technology with the aim to cultivate cactus for food and fodder, but later on the research at BAIF was focused mainly on providing an alternate fodder crop to the farmers living in arid and semi-arid regions of India and to address their livelihood issues (Kauthale *et al*, 2017).

Advance approaches for cactus cultivation

Micropropagation technique of spine-less, vegetable type cactus pear (nopal cactus) was standardized by ICAR-CIAH, Bikaner recently in 2009 (Fig. 1&2) and its morphological and nutritional evaluation (Table 1&2) was done under green house conditions (Saroj *et al*, 2017; Kumar *et al*., 2017).

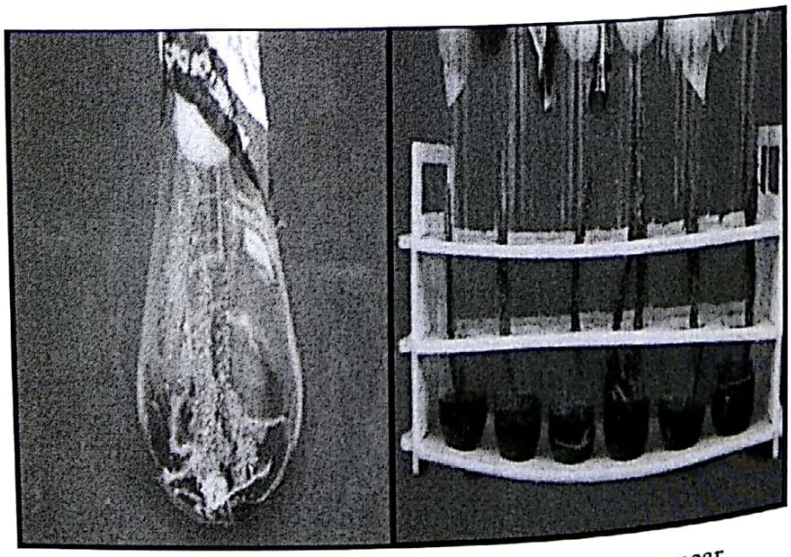


Fig. 1&2: Tissue cultured plants of nopal cactus pear

Table 1: Morphological observations on nopal Cactus pear (vegetable type)

Serial/ Plant Number	Number of cladode/plant (04.02.17)	Number of cladode/ plant (4/3/17)	Days required to reach edible stage	Weight of nopal at edible stage (g)	Length of nopal (cm)	Width of nopal (cm)
1	17	22	23	36.32	16.5	8.0
2	16	22	18	22.52	12.0	6.5
3	16	23	23	39.34	16.7	9.0
4	18	21	18	33.20	13.3	8.2
5	22	29	19	30.73	13.7	7.5
6	25	31	18	22.21	12.0	6.4
7	11	16	24	46.31	18.0	8.7
8	08	11	23	36.94	16.0	7.0
9	19	23	20	27.86	15.4	6.0
10	14	19	19	23.61	13.0	7.0
Average	16.6	21.7	20.5	31.90	14.66	7.63

Table 2: Nutritional evaluation of vegetable type cactus pear

S.N.	Nutrient content	Unit
1.	Moisture content	91-93 %
2.	Dry matter	7-9 %
3.	Ash content	13-15 % (dry weight basis)1 % (wet weight basis)
4.	Mucilage	15-22 % (dry weight basis)
5.	Total phenolics	4.5-7.0 mg/g (dry weight basis)
6.	Flavonoids	200 µg/g (dry weight basis)
7.	Total Antioxidant Activitymg Equi. Vit C/g (dry wt.)	10-16 µg/g (dry weight basis)

Establishment of green house unit

After successful development of tissue culture technique at ICAR-CIAH, Bikaner a green house unit of cactus has been established (Fig. 3). Since demand of cladodes of vegetable type cactus pear is increasing day by day. Therefore, we are at CIAH establishing a field repository in open condition.

Fig. 3: Green house unit established for tissue cultured cactus pear genotype

Field evaluation of different cactus pear genotypes

The cultivation of vegetable type (nopal cactus pear) for human consumption is depends on selection of the spineless varieties. The most important species for nopales production is *Opuntia ficus-indica* (L.) Mill. Now-a-days, it is parts of kitchen or family gardens in arid and semi-arid regions due to nutritional and medicinal properties. Therefore, field evaluation of this nopal cactus is being carried out with other cactus pear existing germplasm at CIAH farm (Fig. 4 & table 3). Five genotypes of cactus pear were evaluated under field condition for field establishment, sprouting, growth, flowering and fruiting. The data regarding these observations is presented under here in tabular form.

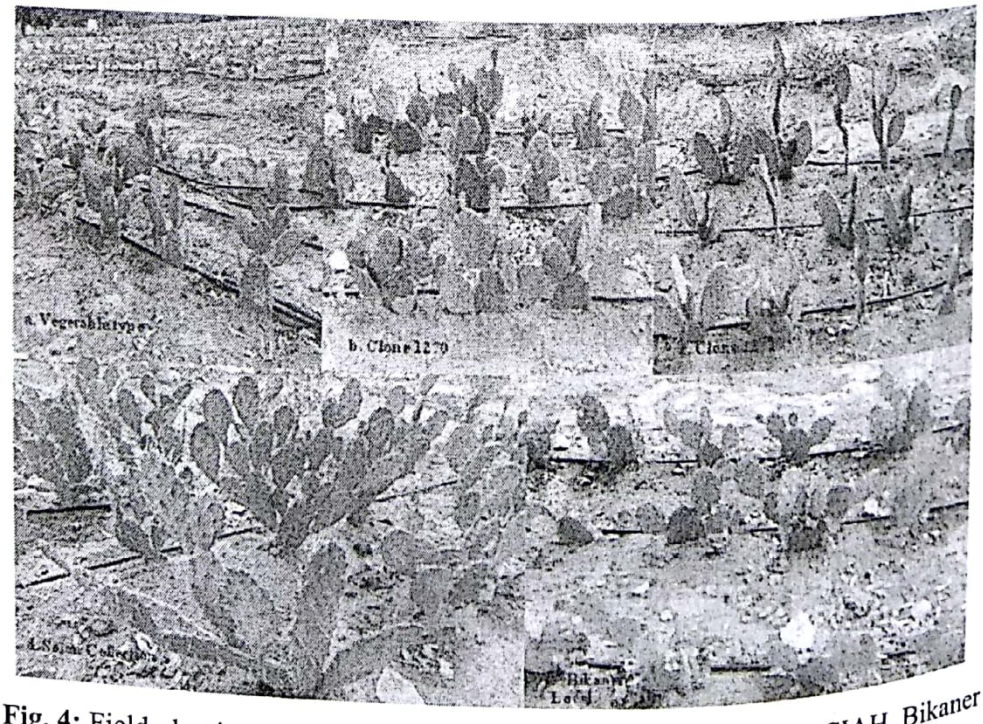
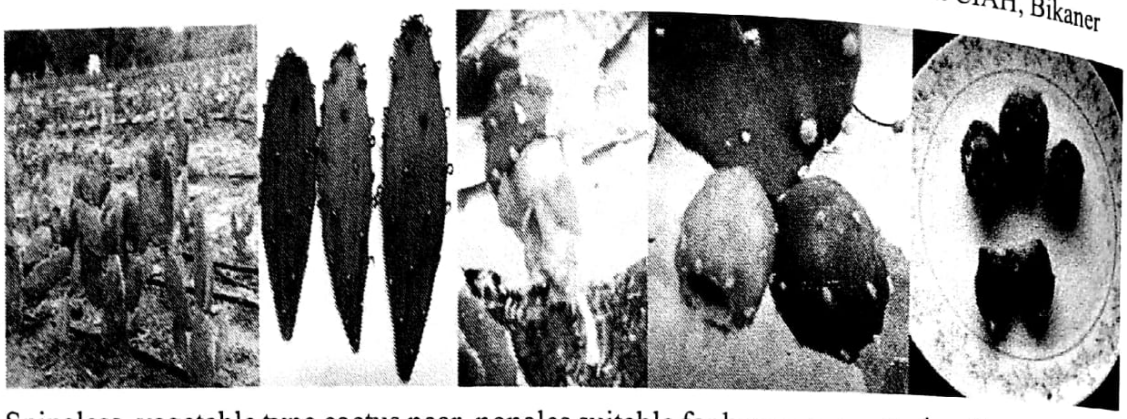


Fig. 4: Field planting of different genotypes of cactus pear at ICAR-CIAH, Bikaner

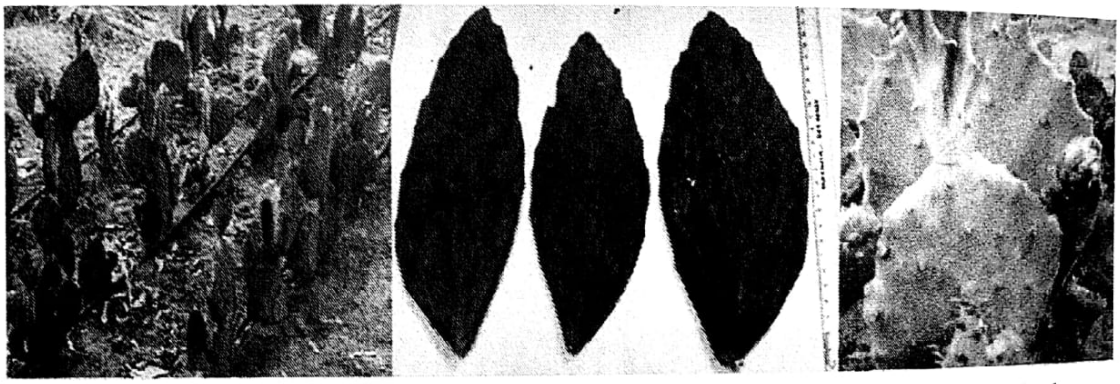
Table 3: Field evaluation of different cactus pear genotypes

Genotype	Field establishment (%)	Mortality (%)	Sprouting	Avg. plant height (cm)	No. of cladode/ plant	Flowering	Fruit per plant	Use
Vegetable type/nopal cactus	76.93	23.04	III	43.90	6- 23	Occurred	1-9	Vegetable, salad, pickle, squash, animal feed, edible, fruit production
Clone 1270	100	0.00	II	45.20	4- 14	Occurred	1-3	Suited for animal feed
Clone 1271	100	0.00	IV	56.60	4- 7	No flowering	-	Animal feed, biofencing
Solan Collection	100	0.00	I	53.30	16- 32	Occurred	1	Biofencing, fruit production
Bikaner Local Collection	100	0.00	V	41.30	7- 10	Occurred	1-8	Biofencing, fruit production

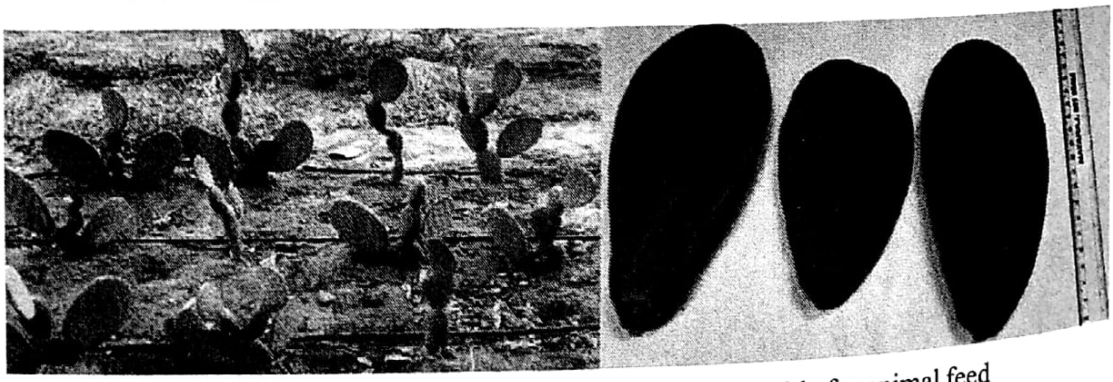
Cladode, flower and fruit variability in cactus pear genotypes available at CIAH, Bikaner



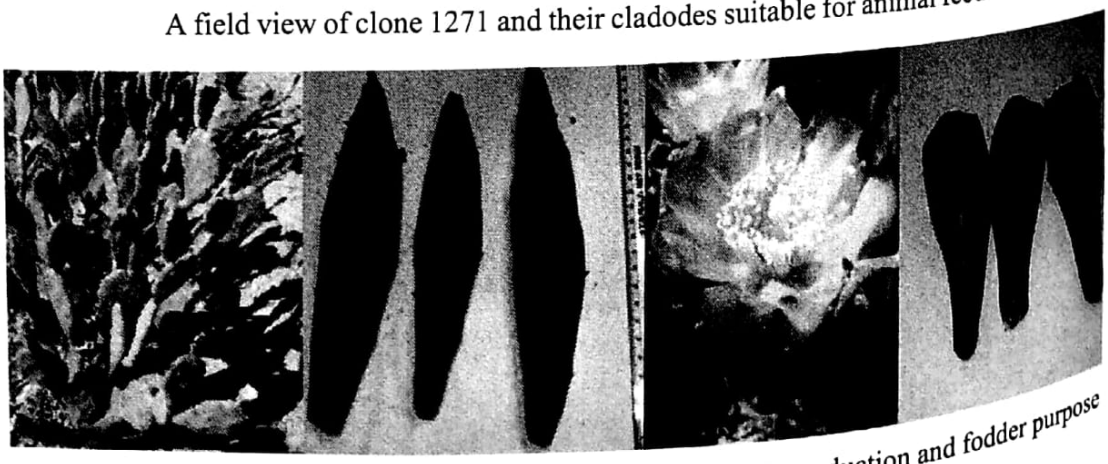
Spineless, vegetable type cactus pear, nopales suitable for human consumption, flower and fruits



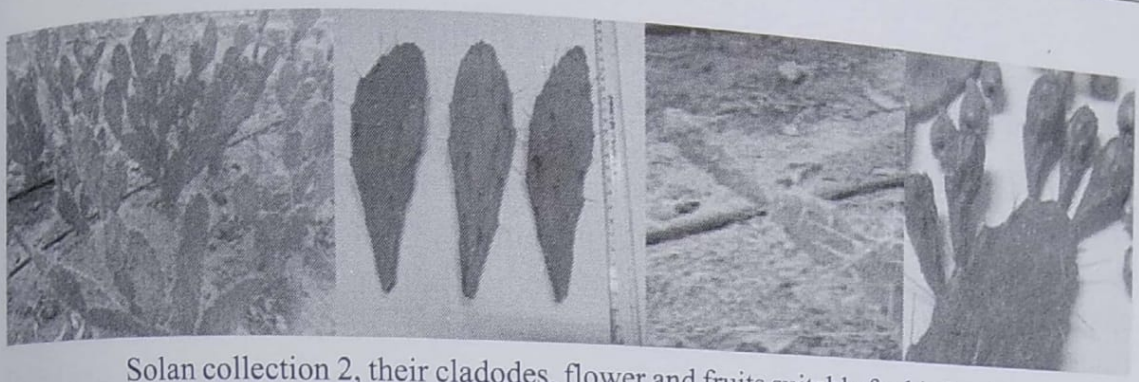
A view of clone 1270 and their cladodes, flower and fruits suitable for animal feed



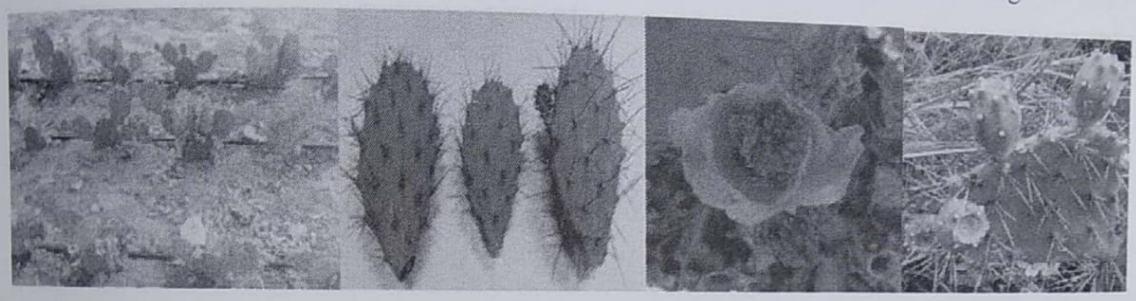
A field view of clone 1271 and their cladodes suitable for animal feed



Solan collection 1 their cladodes, flowers, fruits suited for fruit production and fodder purpose



Solan collection 2, their cladodes, flower and fruits suitable for biofencing



Genotype Bikaner Local, their cladodes, flower, fruits, suitable for fruit production and biofencing

Fig. 5: Variability of different cactus pear genotypes existing at ICAR-CIAH, Bikaner

Earlier Pareek *et al.* (2003) evaluated 51 clones of cactus which were obtained from Texas in pots at CIAH, Bikaner. Clone 1308 was sprouted first (24th day) while clone 1379 took 135 days for sprouting. The average cladode weight was ranged from 66.8 g to 1300 g. Only 3 clones (1269. 1270 and 1271) were flowered after 3 years of planting but fruiting occurred in clone 1270 and 1271. Singh and Singh (2001) conducted a study on growth, cladode yield and quality of vegetable type cactus under Agra (UP) agro-climatic conditions and reported that clone 1308 (vegetable type) was better in all growth, yield and quality attributes than the Nopalea type. Planting of cladodes in East-West direction keeping 1/3 portion under the soil significantly increased the number of roots/ pant, cladode length, early sprouting and biomass production in clone 1270 which is a fodder and fruiting type cactus pear (Singh *et al.* 2002).

Very recently at CIAH, Bikaner, 30 plants of vegetable type cactus pear along with Mount Abu Collection, clone 1308 and 1269 had been planted in the field and evaluated for growth and survival. Clone 1308 was sprouted first than other genotypes. Plant survival was observed good under field condition and growth of clone 1269 was found better than other genotypes.

Potential benefits of cultivating cactus pear in the arid region

Cactus pear is cultivated for about hundreds of years as a food crop, a defensive hedge, rearing cochineal insect for production of dye, as a fodder crop and as a standing buffer fodder for animals during drought periods. It plays a key role in erosion control mechanism and land rehabilitation programmes particularly in

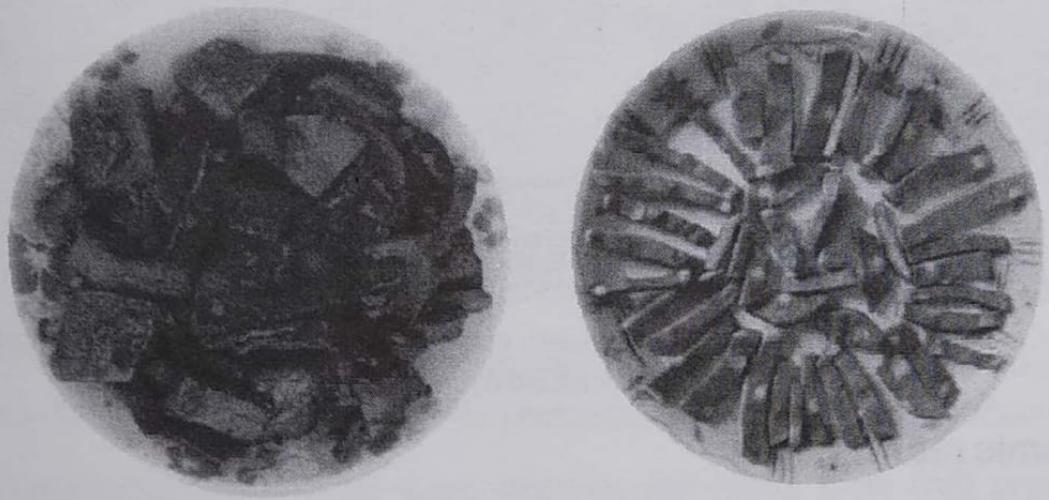
arid and semi-arid regions of the world, a shelter and refuge. Cactus nopals have been long back used as natual, herbal medicine to treat diseases such as ulcer, allergies, fatigue, rheumatism, antiuric and as diuretic agent. Alleviating effects towards alcohol hangover symptoms cactus pear have been used very recently and associated with reduced inflammatory responses after excessive alcohol consumption. The nutritional and medicinal properties of the fresh cactus cladodes have long been known. The bark is a tonic and diuretic, the fruits have cooling and tonic properties and the young buds and the milky juice are astringent (https://books.google.co.in/books?isbn=0124080642). Some of the epithets used for the plant and the fruit such as "Green gold", "fruit for the poor", "treasure under its spines", "world vegetable dromedary", "future plant", "sacred plant" and "monster tree" (Arias Jimenez, 2013a), these names telling the importance of cactus in the work and lives of people because of their resistance to drought and high temperatures and their adaptability to poor soils.

A number of medicinal applications have been reported in several cactus species. Medicinally, components and extracts have been used in treatments of diabetes, cholesterol and immune system health (Knishinsky, 2004). Nopales products played as preventive and therapeutic effects against alcoholism and alcohol addiction. The flavonoids which are extracted from cactus nopales, quercetin 3-methyl appears to be the most potent neuroprotector. A number of traditional foods are prepared from cactus pear, including fruit-based products: jams, juices and nectars; dried fruit; juice concentrates and syrups; and liquors. Pickles, juices, jams and a number of other minimally processed products can be made from cladodes (FAO, 2013). Cacti have been used as live biofencing material for protecting fields from wild animals.

Different types of *cactus species* are being used for research purposes mainly as fodder in arid, semi- arid, rainfed and drought prone areas. However, few institutes like CIAH, Bikaner, CAZRI, Jodhpur, CAFRI, Jhansi, CSSRI, Karnal the focus has recently shifted to the production of vegetable type, spineless cactus genotypes for human consumption as well as animal fodder. Tender nopales (tender cladodes of vegetable type, spineless cacti) can be consumed during the early stages of growth (till light green in colour). Cactus nopal is suitable to use as fresh. It was observed that nopales can be harvested regularly at an interval of 15-20 days when they reach 10 to 15 cm in length and about average weight of 30 g/nopal which can provide an average yield of 1.5 kg tender nopales/plant/year. Cactus nopales are an important part of the human diet and are also used as feed for livestock.

A number of potentially active nutrients and their multifunctional properties are found in nopal which makes it suitable for the production of health-promoting food and food supplements. Mainly nopales are consumed fresh form in Mexico

and canned or pickled nopales exported to particularly Southwestern United States and Texas. Opportunities of several economic products such as fruit, squash of fruit, pickle, ready to serve drinks, colour from fruit and cochineal, cladodes for culinary and salad were prepared at ICAR-CIAH (Fig. 6, 7 & 8), Bikaner and demonstrated to several beneficiaries which can satisfy the product diversification need, increased shelf life and improved human health.



Mix vegetable Salad

Fig. 6: Culinary exploitation of spineless, nopal cactus pear at CIAH, Bikaner

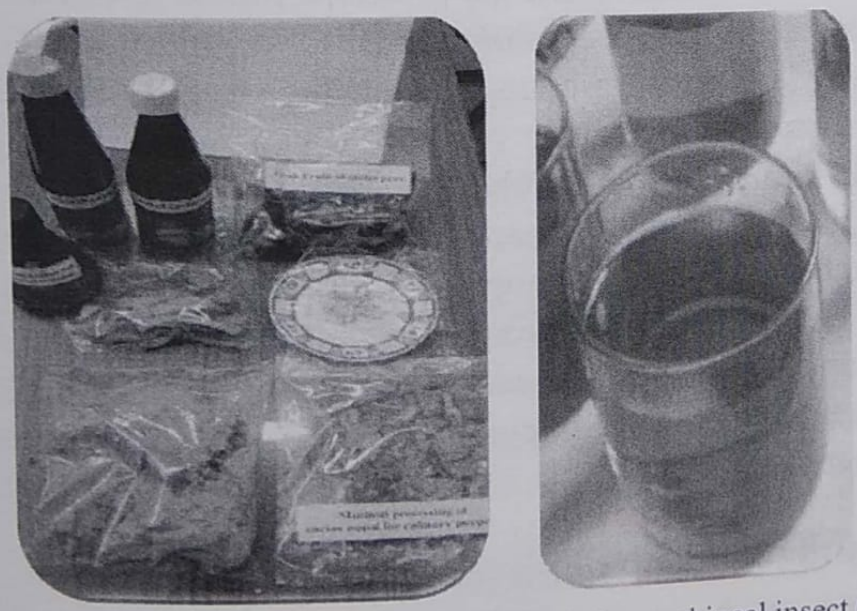


Fig. 7: Syrup, minimal processed nopal, fresh fruits, cochineal insect (*in plate*) for dye preparation and fruit squash made at CIAH, Bikaner

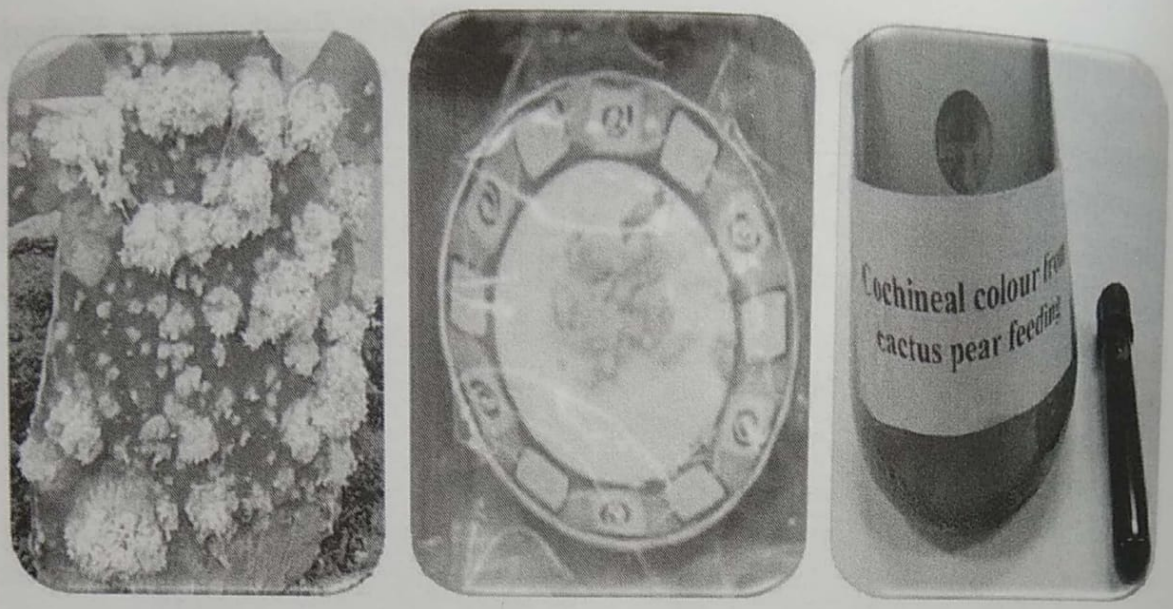


Fig. 8: Cochineal insect reared on nopal cactus, cochineal for dye preparation (*in plate*) and cochineal dye

Economic returns

It has been proved from the intensive R&D efforts made at ICAR-CIAH, Bikaner that cactus pear can be cultivated successfully in arid region with enhanced nutrition and income from the different products of nopal cactus pear. Further, round the year production can be taken under low cost green house condition. Under greenhouse, nopales can be harvested regularly at an interval of 15-20 days with an average yield of 1.5 kg tender nopales per plant per year. Thus, the farmer can get regular income from this crop. Preliminary studies indicated that Rs 150 to 200 per plant per year may be obtained from different fresh products of vegetable nopales, fruits and processed items (such as squash, RTS, pickle, jam, candied products *etc*.) from a full grown plant after 3-4 years of planting. Thus, a farmer can get an income of Rs 500 to 600 per square metre area under green house condition with an estimated benefit cost ratio of 3:1 (Kumar *et al*, 2017).

Future scope and research need for cactus cultivation

Cactus pear traditionally has been used as a valuable health promoting food crop and also has applications in pharmaceutical industries. It has several uses and immense potential to be the food of future. Cactus fruits are popular in several countries and contains important nutritional and health components such betalains, polyphenols and dietary fibre. Although, human interest is increasing with the fruits, recently research also has been carried out to know about its bioactive components and functional properties which have been generated. There are so many future uses of the cactus have been suggested, such as nopal pulp use for the production of shampoos, conditioners, face and body lotions, soaps, hair gels, sun protectors and bio-ethanol production. Cactus juice

extracted from cladodes is one of the most commonly used additives in earthen plaster or improving house paint and mucilage found to purify water. Veterinary phytotherapy using *Opuntia* appeared to be a promising field of research and applicability. Cactus plant can be used for rearing of Cochineal insect for production of attractive red and/ or pink colour dye. Human health concerns about artificial food additives have opened the door of popularity of this dyes and the demand is increasing which encourage the rearing of cochineal insect is a golden opportunity for this crop.

Different new processing technologies have been developed but great challenges are still remain. Therefore, it is important to continue research onto this wonderful crop. There are several future opportunities and advantages of growing cactus pear as a crop discussed hereunder in key points.

a. Different food products and alcoholic and non-alcoholic drinks can be made from young nopales (to promote food and beverage industry)
b. Supplements and feed from nopales and waste from fruit processing, including peel and seeds (for livestock feed industry)
c. Gastric mucosal protectants from mucilage extracts, tablets and capsules of nopal powder and flower extracts (for pharmaceutical industry)
d. Creams, shampoos and lotions from nopal (for cosmetic industry)
e. Fibre and flours from nopales (food supplements industry)
f. Gums from nopales and colorants from fruits (natural additives industry)
g. Binding compounds from mucilage/nopales (importance in construction industry)
h. Biogas from digestion of nopales and factory waste streams, alternatively, lignified nopals burned as fuel-wood (role in energy sector)
i. Soils, organic materials and improved drainage from the use of cactus products (as an agricultural inputs)
j. Artisan crafts can be made from lignified nopales (importance for tourism sector)
k. Use of natural colorants, such as carmine from cochineal insects (role in textile industry)

Conclusion

Cactus pear plays an important role in providing food (human), fodder (livestock) and several economic products for human and animals living in arid and semi-

arid regions, especially during critical periods of the year. There is a need for research to evaluate the effect of different cactus products on human and animal beings as well as methods to improve the nutritive quality of this valuable crop in these regions. Previously, a number of crops were known of little importance and thus not collected, conserved and researched but later on they have been recognised by international research organisations as necessary for agricultural sustainability and food security. This is also happened with cactus pear. The increased interest in this crop specially from potential contribution to agricultural diversification, application to the exploitation of marginal lands and changing environments, benefits as additional income source for farmers living in arid and semi-arid regions of the world. Cactus pear can tolerate and grow successfully in poor and marginal soils, limited water conditions and high temperatures. Therefore, cactus is being cultivated in arid and semi-arid regions of the world.

References

Arias Jimenez, E. 2013. Importancia de la tuna. *Cactusnet Newsletter*, 13: 9–12.

FAO. 2013. Agro-industrial utilization of cactus pear. Rome.

Jose, C.B., Dubeux, Jr., Hichem B.S. and Nefzaoui, A. 2017. Forage production and supply for animal nutrition. *In*: IX International congress on cactus pear and cochineal- CAM crops for a hotter and drier world (Eds. Inglese, P., Mondragon, C., Nefzaoui, A. and Saenz, C.), Coquimbo, Chile.

Kauthale, V., Aware, M. and Punde, K. 2017. Cactus an emerging fodder crop of arid and semi arid India. Booklet by BAIF Development Research Foundation, Pune

Knishinsky, R. 2004. Prickly Pear Cactus Medicine: Treatments for Diabetes, Cholesterol, and the Immune System. Inner Traditions/Bear and Co, Rochester, VT, USA. pp.705.

Kumar, K., Singh, D. and Berwal, MK. 2017. Cactus pear: A multipurpose climate smart crop for higher income in arid zone. In the compendium entitled "Doubling Income through Advance Approaches for Fruits and Vegetables in the Arid Region" (*Eds*. Saroj, P.L., Sharma, B.D. and Jatav, M.K.), ICAR-CIAH, Bikaner, Rajasthan.

Pareek, O.P., Singh, R.S. and Vashishtha, B.B. 2003. Performance of cactus pear (*Opuntia ficus-indica* L. Mill.) clones in hot arid region of India. *J. prof. Ass. Cactus dev.* 5: 121-130.

Russel, C. and Felker, P. 1987. The prickly-pears (*Opuntia spp.*, Cactaceae): A source of human and animal food in semiarid regions. *Econ. Bot.*, 41:433–445.

Saroj, P.L., Singh, D. and Kumar, K. 2017. Culinary exploitation of nopal cactus pear in arid region. *Indian Hort.*, 62 (4): 13-16.

Singh, G. 2003. General Review of Opuntias in India. *Journal of the professional association for cactus development*. 5: 30-46.

Singh, R.S. and Singh, V. 2001. Performance of vegetable type cactus under Indian conditions. *Curr. Agri.*, 25 (1-2): 99-101.

Singh, R.S., Bhargava, R., Sharma, B.D. and Pareek, O.P. 2002. Effect of depth and direction of cladodes planting on growth of cactus pear. *Curr. Agri.*, 26 (1-2): 119-121.

Stintzing F.C., Schieber, A and Carle, R. 2003. Evaluation of colour properties and chemical quality parameters of cactus juices. *Europ. Food Res. Tech.*, 216 (4):303-311.

Ting, I.P. 1985. Crassulacean Acid Metabolism. *Ann. Rev. Plant. Physiol.*, 36: 595-622.